

**UNITED STATES DISTRICT COURT
DISTRICT OF NEW JERSEY**

IMRAN CHAUDHRI, individually,
and on behalf of all others similarly
situated,

Plaintiff,

v.

OSRAM SYLVANIA, INC., and OSRAM
SYLVANIA PRODUCTS, INC.,

Defendants.

Civil Action No.
2:11-CV-05504-SDW-MCA

DECLARATION OF THOMAS PACIORKOWSKI, ESQ.

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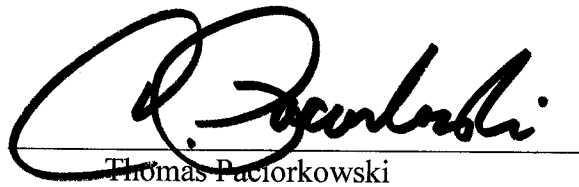
I, Thomas Paciorkowski, Esq., being of full age, hereby declare as follows:

1. I am an Associate at the law firm of Eichen Crutchlow Zaslow & McElroy, LLP, representing the Plaintiff in the above captioned matter.
2. Attached as Exhibit A is a true and correct copy of a print out from Wal-Mart's web site, advertising SilverStar 9004 head lamps.
3. Attached as Exhibit B is a true and correct copy of an article published on February 22, 2012 by The BLT: The Blog of Legal Times, an ALM publication, titled "FTC Settles Charges with Replacement Window Makers Over Savings Claims."
4. Attached as Exhibit C is a true and correct copy of an FTC Press Release dated Feb. 22, 2012.
5. Attached as Exhibit D is a true and correct copy of a glossary of lighting terms published on the Lighting Research Center's web site.
6. Attached as Exhibit E is a true and correct copy of an email I sent to the GE Lighting Institute and the response I received.
7. Attached as Exhibit F is a true and correct copy of a paper presented by General Electric Co. at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, titled, An Iodine Incandescent Lamp with Virtually 100 Per Cent Lumen Maintenance.
8. Attached as Exhibit G is a true and correct copy of a printout from the IEEE Spectrum website.
9. Attached as Exhibit H is a true and correct copy of a printout from the IEEE website.

10. Attached as Exhibit I is a true and correct copy of a printout of an article from the IEEE Spectrum website titled, "Requiem for the Incandescent Lightbulb, A look back at a century of light," dated April 2011.

I declare that the foregoing statements by me are true. I am aware that if any of the statements are willfully false, I may be subject to punishment.

Dated: March 26, 2012



Thomas Paciorek

EXHIBIT

A



Sylvania Silverstar 9004 Automotive Bulb, 2pk

Be the first to write a review

Shop at Walmart

Pickup Information

When will I get this item?

In stores

Price may vary

In Stock for:

Free shipping to store

Enter ZIP code

Find

What's This?

Add to: My List **NEW!**

Product availability, styles, promotions and prices may vary between stores and online.

Item Description

The Sylvania Silverstar 9004 Automotive Bulb provides brighter and whiter light. This high-performance automotive lighting solution offers better down-road and side-road lighting due to its improved brightness.

Sylvania Silverstar 9004 Automotive Bulb, 2pk:

- High performance lighting
- Brighter and whiter light
- Up to 35 percent brighter light
- Up to 30 percent better down-road lighting
- Up to 35 percent better side-road lighting
- Output: 4,000K
- Legal for on-road use
- Model# 9004 ST/2
- Made in the USA

Specifications

Top of Page

Model No.: 9004 SilverStar TWIN

Product in Inches (L x W x H): 3.7 x 3.7 x 3.7

Walmart No.: 001075056

EXHIBIT B

The BLT: The Blog of Legal Times



The **BLT**: The Blog of LegalTimes

An **ALM** Publication

LAW AND LOBBYING IN THE NATION'S CAPITAL

February 22, 2012

FTC Settles Charges with Replacement Window Makers Over Savings Claims

In a warning to marketers, the Federal Trade Commission today settled charges with five companies that claimed energy-efficient replacement windows could save consumers "up to" 35 to 55 percent in heating and cooling bills.

The FTC found that "most customers could never achieve these kinds of results," said James Kohm, associate director of the enforcement division in the Bureau of Consumer Protection, during a call with reporters. "They shouldn't be implying most people are going to receive outlier claims... 'Up to' claims are interpreted by consumers to mean they'll likely receive the benefits."

The five companies — Gorell Enterprises, Inc.; Long Fence & Home, LLLP; Serious Energy, Inc.; THV Holdings LLC; and Winchester Industries — were charged in administrative complaints with violating Section 5 of the FTC Act. The settlements require them to stop making the claims, but do not include monetary penalties, nor do the defendants admit wrongdoing.

Kohm explained that cash penalties are not permitted in such administrative cases, but any future violation carries a stiff fine.

Also, he said it would have been "very hard to determine losses" for consumers who installed the windows expecting mega-savings on energy bills. The amount of energy savings varies by consumer, and depends on factors like whether the old windows were single-pane glass, the home's insulation and climate. "It's highly dependent on individual consumers," he said.

He also noted that consumers replace windows for a variety of reasons such as appearance, and not just for energy savings.

Overall, he estimated that the average true savings on energy bills as a result of new windows is more like 5 to 20 percent.

"We're not claiming these are bad windows," he said. "They just overstated the energy savings."

Posted by [Jenna Greene](#) on February 22, 2012 at 04:10 PM | [Permalink](#)

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Previewing your Comment

Posted by: |

This is only a preview. Your comment has not yet been posted.



Your comment could not be posted. Error type:

Your comment has been saved. Comments are moderated and will not appear until approved by the author. [Post another comment](#)

The letters and numbers you entered did not match the image. Please try again.

As a final step before posting your comment, enter the letters and numbers you see in the image below. This prevents automated programs from posting comments.

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EXHIBIT C



Federal Trade Commission Protecting America's Consumers

For Release: 02/22/2012

Window Marketers Settle FTC Charges That They Made Deceptive Energy Efficiency and Cost Savings Claims

Companies Must Have Scientific Evidence Before Making Marketing Claims

Five companies that sell replacement windows in numerous states will have to stop making exaggerated and unsupported claims about the energy efficiency of their windows, and how much money consumers could save on their heating and cooling bills by having them installed, under settlements with the Federal Trade Commission. The settlements prohibit the companies from making these types of deceptive claims.

"Energy efficiency and cost savings are major factors for many consumers buying replacement windows," said David Vladeck, Director of the FTC's Bureau of Consumer Protection. "The FTC is committed to making sure that the information consumers get is accurate and that marketers can back up the claims they make."

The cases are part of a broad FTC effort to ensure that [environmental marketing](#) is truthful and based on solid scientific evidence. Also today, the agency issued a new consumer education publication called "[Shopping for New Windows](#)," which provides information on factors that affect the energy savings replacement windows are likely to provide; things to consider when shopping for new windows, such as cost, material, style, and installation; and how an energy performance rating label can help consumers choose the windows that are best for their specific needs.

The FTC's complaints allege the five companies engaged in deceptive practices by making unsupported energy efficiency and money-savings claims – in some cases, that consumers could cut their energy bills in half by using replacement windows alone. The companies named in the settlements are: *Gorell Enterprises, Inc.*; *Long Fence & Home, LLLP*; *Serious Energy, Inc.*; *THV Holdings LLC*; and *Winchester Industries*.

Gorell Enterprises, Inc. Based in Pennsylvania, Gorell also operates under the names Gorell Windows & Doors and American Conservatory Systems. It manufactures windows with the "Thermal Master III" glass system and other lines. The company's "40% Energy Savings Pledge" promised consumers savings of at least 40 percent of home fuel consumption for both heating and cooling in the first year after their windows were installed, or they would repay them the difference, up to \$500. According to the FTC's Complaint, Gorell lacked a reasonable basis for claiming that consumers who replace their windows with Thermal Master III windows were likely to achieve residential energy savings of 40 percent or save 40 percent on home heating and cooling costs.

Long Fence & Home, LLLP. Based in Maryland, Long Fence & Home does business under a number of names, including Long Windows. It distributes and installs Serious Energy's Quantum 2 windows with SuperPak glass, among other lines. Long's advertisements in various media have included claims such as "50% Energy Savings Guaranteed," and "save 50% on Energy Bills – or LONG PAYS YOU!" Long also pledged 50% savings on heating and cooling energy usage. Long's website included a "savings calculator" that invited users to enter their average monthly energy bills and click a button to "CALCULATE SAVINGS." According to the FTC, Long's savings claims for the advertised windows were unsubstantiated.

Serious Energy, Inc. Based in California, Serious Energy provides its dealers with marketing materials, including brochures and other information on its website. These materials have included claims such as, "Guaranteed to reduce your heating and cooling use by up to 49%." Serious Energy also offered heating and cooling reduction pledges, varying by dealer, and promised consumers would be paid up to \$500 if they did not realize these savings within one year of when the windows were installed. The FTC alleged that Serious Energy's savings claims for the advertised windows were unsubstantiated.

THV Holdings LLC. Based in Kentucky, THV's telemarketing sales scripts represented that its replacement windows will "cut energy bills in half"; that homeowners will typically see a 35 to 55 percent reduction in monthly energy bills; that "our homeowners have noticed that our windows saved them 35% to 55% off their energy bills," and pledged that its windows systems "will pay for themselves in energy savings alone in 8 years or we will pay the difference . . . our windows are free!!" The FTC charged that THV disseminated the claims in sales scripts for the company's THV Compozit windows with Alter-Lite triple pane glass. The FTC also charged that THV lacked a reasonable basis for its savings claims.

Winchester Industries. Based in Pennsylvania, Winchester manufactures Bristol and WinterLock Super Triple-E, A-Plus with Alpha-10 windows. In its promotional materials, Winchester claimed that consumers would "reduce energy costs by 47%" and that "the triple-paned design of some replacement windows, such as Bristol windows, can also produce energy savings of up to 50% a year." Winchester's consumer testimonials claimed similar results, and the company pledged a heating and cooling reduction of at least 47 percent. The FTC charged that Winchester lacked a reasonable basis for making its energy savings claims for its windows.

The proposed orders settling the FTC's charges against the five companies are designed to prevent the companies from engaging in similar deceptive marketing practices in the future.

Part I of the proposed settlements prohibits each company from claiming:

- that consumers who replace their current windows with those of the company will achieve up to, or a specified amount or percentage of energy savings, or a reduction in their heating or cooling costs; or
- that the company guarantees or pledges that consumers who replace their windows with the company's windows will achieve such energy savings;

unless the claim is non-misleading and when the company makes the claim, it has competent and reliable scientific evidence to substantiate that all or almost all consumers are likely to achieve the maximum savings claimed.

In addition, if the company claims or guarantees that consumers will achieve specific energy savings or reduced heating or cooling costs under certain circumstances (for example, by replacing a window made of a certain material in a specific region of the country), it must clearly and prominently disclose those circumstances near where the claim or guarantee is made. The company also must be able to substantiate that all or almost all consumers are likely to see the maximum savings claimed under those circumstances.

Part II of the proposed settlements prohibits each company from making claims:

- that a specific number or percentage of consumers who replace their windows with the company's will achieve energy savings or reduced heating or cooling costs; or
- about energy consumption, energy costs, heating and cooling costs, or other insulating properties or energy-related efficacy;

unless the representation is non-misleading and is substantiated by reliable scientific evidence.

As noted above, the proposed orders require each company to substantiate savings claims that include the words "up to" – for example, if they claim consumers will save "up to" a certain amount of money, or achieve energy savings "up to" a certain amount, it must have competent and reliable scientific evidence to substantiate that all or almost all consumers are likely to achieve the maximum savings claimed.

The proposed orders with Serious Energy, Gorell, THV, and Winchester include an additional provision designed to make sure they do not give misleading information to their distributors that could be passed on to consumers. The proposed order with THV also requires it to conduct a training program to help principals, officers, managers, employees, and representatives avoid misleading claims. The other four firms are required to broadly distribute copies of the order within each company to help ensure their employees' compliance.

The Commission vote to issue the administrative complaints and accept the consent agreement packages containing the proposed consent orders for public comment was 3-0, with Commissioner J. Thomas Rosch abstaining, in each case. The FTC will publish a description of the consent agreement packages in the Federal Register shortly. The agreements will be subject to public comment for 30 days, beginning today and continuing through March 23, 2012, after which the Commission will decide whether to make the proposed consent orders final. The FTC acknowledges the valuable assistance of the Washington State Attorney General's Office in the investigation of this matter.

Interested parties can submit written comments electronically or in paper form by following the instructions in the "Invitation To Comment" part of the "Supplementary Information" section. Comments in electronic form should be submitted using these links and following the instructions on the web-based form:

- [Submit comment on Gorell Enterprises](#)
- [Submit comment on Long Fence & Home](#)
- [Submit comment on Serious Energy](#)
- [Submit comment on THV Holdings](#)
- [Submit comment on Winchester Industries](#)

Comments in paper form should be mailed or delivered to: Federal Trade Commission, Office of the Secretary, Room H-113 (Annex D), 600 Pennsylvania Avenue, N.W., Washington, DC 20580. The FTC is requesting that any comment filed in paper form near the end of the public comment period be sent by courier or overnight service, if possible, because U.S. postal mail in the Washington area and at the Commission is subject to delay due to heightened security precautions.

NOTE: The Commission issues an administrative complaint when it has "reason to believe" that the law has been or is being violated, and it appears to the Commission that a proceeding is in the public interest. The complaint is not a finding or ruling that the respondent has actually violated the law. A consent agreement is for settlement purposes only and does not constitute an admission by the respondent that the law has been violated. When the Commission issues a consent order on a final basis, it carries the force of law with respect to future actions. Each violation of such an order may result in a civil penalty of up to \$16,000.

The Federal Trade Commission works for consumers to prevent fraudulent, deceptive, and unfair business practices and to provide information to help spot, stop, and avoid them. To file a complaint in English or Spanish, visit the FTC's online [Complaint Assistant](#) or call 1-877-FTC-HELP (1-877-382-4357). The FTC enters complaints into Consumer Sentinel, a secure, online database available to more than 2,000 civil and criminal law enforcement agencies in the U.S. and abroad. The FTC's website provides free information on a variety of [consumer topics](#). Like the FTC on [Facebook](#) and follow us on [Twitter](#).

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(Window Cases.final)

(FTC File Nos. 1123057, THV Holdings; 1023171, Winchester Industries; 1123001, Serious Energy; 1123005, Long Fence & Home; and 1123053, Gorell Enterprises)

E-mail this News Release

If you send this link to someone else, the FTC will not collect any personal information about you or the recipient.

Related Items:

[In the Matter of Gorell Enterprises, Inc.](#)

FTC File No. 112 3053

[In the Matter of Long Fence & Home, LLLP](#)

FTC File No. 112 3005

[In the Matter of Serious Energy, Inc.](#)

FTC File No. 112 3001

[In the Matter of THV Holdings LLC](#)

FTC File No. 112 3057

[In the Matter of Winchester Industries](#)

FTC File No. 102 3171

For Consumers:

- [Shopping for New Windows](#)

Last Modified: Thursday, February 23, 2012

EXHIBIT D



Volume 6 Issue 2

September 2002



Glossary

Sources of term definitions: National Lighting Product Information Program (NLPiP), Lighting Research Center's Lighting Education Online, the IEEE Standard Dictionary of Electrical and Electronics Terms (IEEE Std 100-1996).

A-lamp	The incandescent lamp most commonly used in North American households. The "A" designation refers to the lamp's bulbous shape.
active power	the system input power (in watts) for a lamp-ballast combination.
amalgam	An alloy of mercury with other metals. Some CFLs use a mercury amalgam rather than standard mercury. An amalgam keeps mercury pressure in the discharge near its optimal value as lamp temperature changes. Amalgam lamps can produce more than 90 percent of maximum light output over a wide temperature range, but they can take longer to reach their full light output when started.
ambient temperature	The temperature of the surrounding air that comes into contact with the lamp and ballast. Ambient temperature affects the light output and active power of fluorescent lamp/ballast systems. Each fluorescent lamp-ballast system has an optimum ambient temperature at which it produces maximum light output. Higher or lower temperatures reduce light output. For purposes of lamp/ballast tests, ambient temperature is measured at a point no more than 1 meter (3.3 feet) from the lamp and at the same height as the lamp.
amplitude	The maximum absolute value attained by a periodic wave.
ANSI code	American National Standards Institute (ANSI) code that indicates the electrical operating designation of the lamp, which must match that of the ballast.
aperture	The diameter in the opening of a downlight, in inches (in.). Sometimes manufacturers will round up to the next whole-inch increment.
aperture diameter	The diameter of a reflector cone opening, expressed in inches.
apparent power	The product of root-mean-square (rms) voltage and rms current.
application	The use to which a lighting system will be put; for example, a lamp may be intended for indoor residential applications.
arc tube	An envelope, usually quartz or ceramic that contains the arc of a discharge light source.
average rated life	The number of hours at which half of a large group of product samples fail under standard test conditions. Rated life is a median value; any lamp or group of lamps may vary from the published rated life.
ballast	A device required by electric-discharge light sources such as fluorescent or HID lamps to regulate voltage and current supplied to the lamp during start and throughout operation.
ballast access	The opening through which the ballast in a luminaire can be installed or replaced, either through the aperture or from above the luminaire.
ballast efficacy factor (BEF)	Sometimes called ballast efficiency factor, ballast efficacy factor is the ratio of the ballast factor to the active power (in watts), usually expressed as a percent. It is used as a relative measurement of the system efficacy of the fluorescent lamp/ballast combination.
ballast factor (BF)	The ratio of the light output of a fluorescent lamp or lamps operated on a ballast to the light output of the lamp(s) operated on a standard (reference) ballast. Ballast factor depends on both the ballast and the lamp type; a single ballast can have several ballast factors depending on lamp type.
ballast rated life	The number of hours at which half of a group of ballasts fail under standard test conditions. Rated life is a median value of life expectancy; any ballast, or group of ballasts, may vary from the published rated life.
barn doors	Typically, four adjustable shields that are attached to the face of the luminaire to reduce glare.
beam angle	The angle at which luminous intensity is 50 percent of the maximum intensity.
beam appearance	The description of the beam's image on a wall as determined by subjective visual evaluations of each lamp. The descriptive categories used are smooth, cloud, two-contour, ripple, and variegated.
beam spread	The width of a light beam, expressed in degrees. The beam of light from a reflector-type lamp (PAR, R, ER, or MR) can be thought of as a cone. The beam spread is the angular width of the cone. Common beam spreads are known as spot, narrow, narrow flood, and flood.
bi-level switching	Control of light source intensity at two discrete levels in addition to off.

bin	To sort or classify light sources (such as light emitting diodes) into groups according to their luminous intensity or color appearance.
blackbody radiator	A temperature radiator of uniform temperature whose radiant output in all parts of the spectrum is the maximum obtainable from any temperature radiator at the same temperature. Such a radiator is called a blackbody because it absorbs all the radiant energy that falls upon it. All other temperature radiators can be classed as non-blackbodies. Non-blackbodies radiate less in some or all wavelength intervals than a blackbody of the same size and the same temperature.
Brewster's angle	The incident angle of light on the surface of a medium for which the reflected and transmitted light are perpendicular to each other. This angle depends on the refractive index of the medium. It defines the angle of maximum polarization for a medium.
brownout circuitry	For exit signs, brownout circuitry is designed to switch the sign over to battery supply if the voltage of the utility-supplied power drops below a specified value. Brownout circuitry is an option for some signs.
bulb designation	An abbreviation of the shape and size of a lamp's outer envelope. The letter or letters indicate the shape and the numbers indicate the bulb's maximum diameter in eighths of an inch.
bulb finish	The coating, if any, that is applied to the inside surface of the bulb. Finishes are either clear, phosphor coated, or diffuse.
candela	The Systeme International d'Unities (SI) of luminous intensity. One candela is one lumen per steradian. Formerly, candle.
capacitor	A device used in electric circuitry to temporarily store electrical charge in the form of an electrostatic field. In lighting, a capacitor is used to smooth out alternating current from the power supply.
cathode-disconnect ballast	An electromagnetic ballast that disconnects the electrode-heating circuit after the lamps are started. Cathode-disconnect ballasts operate lamps at 60 hertz; they are sometimes called "hybrid" or "low-frequency electronic" ballasts. They operate lamps at lower power than other magnetic ballasts that produce similar light output.
center beam candlepower (CBCP)	Center beam candlepower is the luminous intensity at the center of a beam, expressed in candelas (cd).
chromaticity	The dominant or complementary wavelength and purity aspects of the color taken together, or of the aspects specified by the chromaticity coordinates of the color taken together. It describes the properties of light related to hue and saturation, but not luminance (brightness).
CIE	Abbreviated as CIE from its French title Commission Internationale de l'Eclairage, the International Commission on Illumination is a technical, scientific, and cultural organization devoted to international cooperation and exchange of information among its member countries on matters relating to the science and art of lighting.
coefficient of utilization (CU)	Coefficient of utilization is the ratio of the luminous flux (lumens) received on a plane to the light output (lumens) of the lamps. Coefficient of utilization depends on luminaire efficiency, distribution of light from the luminaire, size and shape of the room, and reflectances of surfaces in the room. Specifiers use the coefficient of utilization to evaluate how effectively a luminaire delivers light to a workplane.
color appearance	The resultant color perception that includes the effects of spectrum, background contrast, chromatic adaptation, color constancy, brightness, size and saturation.
color consistency	The measure of how close in color appearance random samples of a lamp or source tend to be.
color matching	The action of making a color appear the same as a given color. Often used as a method of evaluating the ability of a light source to render colors faithfully.
color rendering	A general expression for the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source.
color rendering index (CRI)	A rating index commonly used to represent how well a light source renders the colors of objects that it illuminates. For a CRI value of 100, the maximum value, the colors of objects can be expected to be seen as they would appear under an incandescent or daylight spectrum of the same correlated color temperature (CCT). Sources with CRI values less than 50 are generally regarded as rendering colors poorly, that is, colors may appear unnatural.
color shift	The change in a lamp's correlated color temperature (CCT) at 40% of the lamp's rated life, in kelvin (K).
color stability	The ability of a lamp or light source to maintain its color rendering and color appearance properties over its life. The color properties of some discharge light sources may tend to shift over the life of the lamp.
color variation	Lamps of the same type made by the same manufacturer may exhibit a certain degree of variation in color, even when operated under the same conditions and seasoned for the same amount of time.
combined uncertainty	Combined uncertainty is calculated by finding the sum of the squares of sample random variability (standard deviation) and laboratory measurement uncertainty and taking the square root of that sum.

compact fluorescent lamp (CFL)	A family of single-ended fluorescent-discharge light sources with small-diameter [16-millimeter (5/8-inch) or less] tubes.
compatible ballasts	An abbreviated list of common ballasts that will provide the necessary circuitry for a photosensor to operate correctly. Other ballasts may also be compatible; contact the photosensor manufacturer for details.
conduction	The process of removing heat from an object via physical contact with other objects or materials, usually metals.
constant-wattage autotransformer (CWA)	The most common type of ballast used for HID lamps, it maintains a constant power (wattage) supply to the lamp when system input voltage fluctuates.
continuous dimming	Control of a light source's intensity to practically any value within a given operating range.
continuously variable signal	A signal that communicates data that can have a theoretically unlimited number of possible values between two end points. Examples include voltage, temperature, and illuminance.
contrast	Also known as luminance contrast, it is the relationship between the luminances of an object and its immediate background.
control signal range	The range of the electrical signal (in volts) that a control device uses to signal the dimming level to a ballast.
convection	The process of removing heat from an object through the surrounding air.
correlated color temperature (CCT)	A specification for white light sources used to describe the dominant color tone along the dimension from warm (yellows and reds) to cool (blue). Lamps with a CCT rating below 3200 K are usually considered warm sources, whereas those with a CCT above 4000 K usually considered cool in appearance. Temperatures in between are considered neutral in appearance. Technically, CCT extends the practice of using temperature, in kelvins (K), for specifying the spectrum of light sources other than blackbody radiators. Incandescent lamps and daylight closely approximate the spectra of blackbody radiators at different temperatures and can be designated by the corresponding temperature of a blackbody radiator. The spectra of fluorescent and LED sources, however, differ substantially from blackbody radiators yet they can have a color appearance similar to a blackbody radiator of a particular temperature as given by CCT.
cosine distribution	A property of a light source such that its luminous intensity in a particular direction is proportional to the cosine of the angle from the normal to the source.
CSA	Canadian Standards Association.
current crest factor (CCF)	Defined as the peak current divided by the root-mean-square (rms) current of a lamp. Current crest factor ranges from 1 to infinity. ANSI requires current crest factor to be less than 1.7. Lamp manufacturers usually will not warranty their lamps when operated on a ballast having a current crest factor greater than 1.7.
current THD	A measure of the degree to which the current waveform deviates from sinusoidal, expressed as a percentage. See total harmonic distortion (THD).
cutoff angle	The angle of light distribution from a luminaire, measured upward from nadir, between the vertical axis and the first line at which the bare source (lamp) is not visible.
cutoff classification	The classification system of the Illuminating Engineering Society of North America (IESNA) that describes the light distribution of an outdoor luminaire. Cutoff classifications define the luminous intensity limits in two illumination zones that occur within the range of 80° to 180° above nadir. North America (IESNA) that describes the light distribution of an outdoor luminaire. Cutoff classifications define the luminous intensity limits in two illumination zones that occur within the range of 80° to 180° above nadir.
cutoff luminaire	IESNA classification that describes a luminaire having a light distribution in which the candela per 1000 lamp lumens does not numerically exceed 25 (2.5%) at or above an angle of 90° above nadir, and 100 (10%) at or above a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
degree of polarization	A measure of the amount of light polarization ranging from 0 to 100 percent.
dichroic coating (dichroic filter)	A multi-layer coating that transmits certain wavelengths and reflects those not transmitted.
diffuser material	Diffusers scatter the light from a luminaire in all directions. Most diffusers in commodity residential-grade luminaires are made of plastic, usually acrylic or polycarbonate. Other materials include glass and alabaster.
dimming ballast	A device that provides the ability to adjust light levels by reducing the lamp current. Most dimming ballasts are electronic.
direct digital control (DDC)	The technology used by the components of a distributed control system. Direct digital control modules exchange digitally encoded signals with each other, indicating the status of devices connected to the network and executing commands when appropriate. Each module contains a programmable microprocessor, hardware for at least one type of network connection, and some means of detecting or changing a device's status.

direct light	Light emitted by a luminaire in the general direction of the task to be illuminated. The term usually refers to light emitted in a downward direction.
direct luminaire	A luminaire that emits light in the general direction of the task to be illuminated. The term usually refers to luminaires that emit light in a downward direction.
direct uplight	Light emitted upward by a luminaire.
disability glare	A type of glare that causes a loss of visibility from stray light being scattered within the eye.
discomfort glare	The sensation of annoyance or even pain induced by overly bright sources.
distributed control system	A control system in which the computing hardware and software are contained in a network of control modules or multi-circuit control panels physically distributed throughout the facility.
driver	For light emitting diodes, a device that regulates the voltage and current powering the source.
dynamic outdoor lighting	Outdoor lighting that varies light level or other characteristics automatically and precisely in response to factors such as vacancy or the type of use of an outdoor location.
efficacy	The ratio of light output (in lumens) to input power (in watts), expressed as lumens per watt (LPW).
efficacy	The ratio of the light output of a lamp (lumens) to its active power (watts), expressed as lumens per watt.
electrode preheat current	The current flowing through a lamp's electrodes to heat them during starting.
electrodes	The structure that serves as the electrical terminals at each end of electric discharge lamps.
electromagnetic interference (EMI)	The interference of unwanted electromagnetic signals with desirable signals. Electromagnetic interference may be transmitted in two ways: radiated through space or conducted by wiring. The Federal Communications Commission (FCC) sets electromagnetic interference limits on fluorescent lighting systems in FCC Part 18.
electromagnetic wave	A wave composed of perpendicular electrical and magnetic fields. The wave propagates in a direction perpendicular to both fields.
electronic ballast	A ballast that uses electronic components instead of a magnetic core and coil to operate fluorescent lamps. Electronic ballasts operate lamps at 20 to 60 kHz, which results in reduced flicker and noise and increased efficacy compared with ballasts that operate lamps at 60 Hz.
emergency options	Refers to options available when exit signs are operated on a non-utility power supply such as a generator, a central battery unit that operates several exit signs, or an individual rechargeable battery. Options include whether or not the exit sign increases the brightness of the light source if the utility-supplied power fails.
field of view	The area covered by an occupancy sensor, often reported (for wall-mounted sensors) as a horizontal field of view or (for ceiling-mounted sensors) as the solid angle of the cone-shaped coverage area.
filter	A device that allows currents at certain frequencies to pass while those at other frequencies are blocked. Filters reduce conducted electromagnetic waves by grounding the current or by increasing the impedance to a specific frequency.
fixture	A complete lighting unit consisting of lamp or lamps and the parts designed to distribute the light, position and protect the lamp(s), and connect the lamp(s) to the power supply. (Also referred to as luminaire.)
flicker	A rapid and continuous change in light levels caused by the modulation of the light output from fluorescent lamps.
fluorescent lamp	A low-pressure mercury electrical-discharge lamp in which a phosphor coating on the inside of the glass tubing transforms most of the ultraviolet energy created inside the lamp into visible light.
footcandle (fc)	A measure of illuminance in lumens per square foot. One footcandle equals 10.76 lux, although for convenience 10 lux commonly is used as the equivalent.
frequency	The number of cycles completed by a periodic wave in a given unit of time. Frequency is commonly reported in cycles per second, or hertz (Hz).
full cutoff luminaire	IESNA classification that describes a luminaire having a light distribution in which zero candela intensity occurs at or above an angle of 90° above nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10%) at or above a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
full-spectrum color index (FSCI)	A mathematical transformation of full-spectrum index into a zero to 100 scale, where the resulting values are directly comparable to color rendering index. An equal energy spectrum is defined as having an FSCI value of 100, a "standard warm white" fluorescent lamp has an FSCI value of 50, and a monochromatic light source (e.g., low pressure sodium) has an FSCI value of 0.

full-spectrum index (FSI)	A mathematical measure of how much a light source's spectrum deviates from an equal energy spectrum, based on the slope of its cumulative spectrum.
fully shielded luminaire	A luminaire that emits no direct uplight, but which has no limitation on the intensity in the region between 80° and 90°.
fundamental	The component of a periodic wave that has the lowest frequency. It is also called the first-order harmonic.
gamut area	A measure of color rendering based upon volume in color space. It is the range of colors achievable on a given color reproducing medium (or present in an image on that medium) under a given set of viewing conditions.
gas-discharge lamps	An electric lamp that produces light from gas atoms excited by an electric current.
glare	The sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort, or loss in visual performance and visibility.
glow current	The flow of electrons away from a rapid-start lamp's electrodes during preheating. The higher the glow current, the faster the electrodes' emissive coating degrades, increasing lamp-end darkening and reducing lamp life.
grid	The combination of electric power plants and transmission lines operated by an electric utility.
grounded	A circuit or metal object that is connected to the earth at one or more points. Done mostly for safety, grounding also reduces electromagnetic waves.
halo-phosphors	Also referred to as halophosphates. Phosphors are the white powder inside fluorescent lamps that fluoresces (emits visible light) when excited by the ultraviolet radiation produced by the mercury vapor that is energized by the electric arc sustained inside the lamp. Phosphors are used to achieve high efficiency, good color rendering, and low lamp lumen depreciation. Halo-phosphors, however, are limited in their ability to provide a high color rendering index without sacrificing light output and are often mixed with other phosphors.
halogen cycle	Halogen incandescent lamps are in the same family as standard incandescent lamps. The basic operating principle is the same, except that chemicals called halogens are introduced in the gas fill. When electricity passes through the lamp's filament, it is heated until it glows and emits light. In this process, tungsten from the filament evaporates and, over the life of the lamp, causes the glass bulb wall to slowly blacken and the filament to disintegrate until the lamp fails. Halogens remove evaporated tungsten from the glass wall and redeposit it back onto the filament. As a result, tungsten does not build up on the bulb, so the light output does not degrade as rapidly.
halogen lamp	An incandescent lamp that uses a halogen fill gas. Halogen lamps have higher rated efficacies and longer lives than standard incandescent A-lamps.
halophosphates	The class of phosphors commonly used in fluorescent lamps. Halophosphates are limited in their ability to provide a high color rendering index without sacrificing light output. Standard T12 lamps containing halophosphates are the most common and least expensive fluorescent lamps, but United States federal regulations require that all fluorescent lamps must meet minimum efficiency and CRI standards, and 40-watt T12 halophosphate lamps do not meet these standards. T8 lamps usually contain both halophosphates and rare-earth phosphors.
harmonic	For a distorted waveform, a component of the wave with a frequency that is an integer multiple of the fundamental.
harmonic distortion	Distorted waveshapes contain components with frequencies that are multiples of the fundamental frequency. These higher frequency components are known as harmonics.
harmonics	Distortions of a periodic sinusoidal waveform represented as a harmonic series of sinusoidal waveforms of different amplitude and phase. A harmonic series is a group of different frequency waveforms that are multiples of the lowest or fundamental frequency.
heat sinking	Adding a material, usually metal, adjacent to an object in order to cool it through conduction.
high-intensity discharge (HID)	An electric lamp that produces light directly from an arc discharge under high pressure. Metal halide, high-pressure sodium, and mercury vapor are types of HID lamps.
high-pressure sodium (HPS)	A high-intensity discharge lamp type that uses sodium under high pressure as the primary light-producing element. HPS lamps produce light with a correlated color temperature (CCT) of approximately 2000 kelvins, although CCTs for lamps having higher CRI values range from 2200 to 2700 kelvins. Standard lamps have a CRI value of 22; others have CRI values from 60 to 80. HPS lamps are among the most efficient light sources, with efficiencies as high as 150 lumens per watt, although those with higher CRI values have efficiencies as low as 25 lumens per watt.
high-wattage compact fluorescent lamp	Abbreviated as HW-CFL, sometimes called "high lumen CFLs", these lamps are a larger cousin to regular CFLs, usually much larger in size and with higher wattages and light output.
horizontal illuminance	The average density of luminous flux incident on a horizontal surface, measured in footcandles (fc) or lux (lx). One fc equals 10.76 lx.
horizontal rotation range	The total angular horizontal rotation of the lamp-reflector assembly.

hue	The attribute of a light source or illuminated object that determines whether it is red, yellow, green, blue, or the like.
ignitor	A device, either by itself or in association with other components, that generates voltage pulses to start discharge lamps.
illuminance	The amount of light (luminous flux) incident on a surface area. Illuminance is measured in footcandles (lumens/square foot) or lux (lumens/square meter). One footcandle equals 10.76 lux, although for convenience 10 lux commonly is used as the equivalent.
illumination	The process of using light to see objects at a particular location.
impedance	A measure of the total opposition to current flow in an alternating current circuit. The unit of impedance is the ohm Ω .
incident angle	The angle between a ray of light reaching a surface and a line normal (perpendicular) to that surface.
indication	The process of using a light source as something to be seen as in signaling.
indirect lighting	Light arriving at a surface after reflecting from one or more surfaces (usually walls and/or ceilings) that are not part of the luminaire.
infrared radiation	Any radiant energy within the wavelength range of 770 to 106 nanometers is considered infrared energy. (1 nanometer = 1 billionth of a meter, or 1×10^{-9} m).
initial light output	A lamp's light output, in lumens, after 100 hours of seasoning.
instant start	A method of starting fluorescent lamps in which the voltage that is applied across the electrodes to strike the electric arc is up to twice as high as it is with other starting methods. The higher voltage is necessary because the electrodes are not heated prior to starting. This method starts the lamps without flashing. It is more energy efficient than rapid or preheat starting, but results in greater wear on the electrodes during starting. The life of instant-start lamps that are switched on and off frequently may be reduced by as much as 25 percent relative to rapid-start operation. However, for longer burning cycles (such as 12 hours per start), there may be no difference in lamp life for different starting methods.
intensity (luminous intensity)	Total luminous flux within a given solid angle, in units of candelas, or lumens per steradian.
interoperability	The ability to communicate such information as temperature, illuminance levels, status of security devices, and occupancy among building systems and their controls.
inverter	Also known as "power inverter." A device used to convert direct current (dc) electricity into alternating (ac) current.
irradiance	The density of radiant flux incident on a surface.
isotemperature	A set of coordinates within which all points have the same temperature. In a color space diagram, isotemperature lines represent lights with identical correlated color temperatures.
junction temperature	For light-emitting diodes, the temperature of the light-emitting portion of the device (see PN junction), which is inversely correlated with its light output.
Kelvin	Color temperature is measured in degrees Kelvin, which indicate the hue of a specific type of light source. Higher temperatures indicate whiter, "cooler" colors, while lower temperatures indicate yellower, "warmer" colors.
lamp	A radiant light source.
lamp base position	The location of the lamp socket, either in the center of the top of the ballast or on the side of the ballast. Modular ballasts for circular compact fluorescent lamps (CFLs) have a lamp socket located at the end of a wiring harness.
lamp current	The current flowing between a lamp's electrodes during operation.
lamp efficacy	The ratio of the light output of a lamp (lumens) to its active power (watts), expressed as lumens per watt (LPW).
lamp electrode voltage	Voltage to the electrodes to operate a lamp.
lamp envelope	The shape of either the bare lamp or the capsule surrounding the lamp. Common shapes include quad, triple tube, four-tube, coiled tube, A-line, circular, square, globe, capsule (bullet), reflector, and decorative.
lamp life	The median life span of a very large number of lamps (also known as the average rated life). Half of the lamps in a sample are likely to fail before the rated lamp life, and half are likely to survive beyond the rated lamp life. For discharge light sources, such as fluorescent and HID lamps, lamp life depends on the number of starts and the duration of the operating cycle each time the lamp is started.

lamp lumen depreciation (LLD)	The reduction in lamp light output that progressively occurs during lamp life.
lamp operating current	Current flowing through a lamp during normal operation.
lamp quantity and type	The number of lamps (in parentheses) used by the luminaire, followed by a generic designation indicating the type.
lamp rated life	The number of operating hours at which half of a large group of product samples are expected to fail. The rated life is a median value of life expectancy; individual lamp life may vary considerably from the published rated life and operating conditions (e.g., temperature, hours per start) may affect actual life because rated life is based on standard test conditions. In addition, the way a product fails can vary by technology. For example, incandescent lamps abruptly stop producing any light while LEDs are considered to have failed when their light output drops below a certain fraction of the initial level.
lamp shield type	The material used in a luminaire to shield the lamp from the environment. Lamp shields are required by Underwriters Laboratories for some lamp types.
lamp starting current	Current flowing through a lamp during starting operation.
light loss	The reduced light output caused by a circuit-level power reducer expressed as a percentage of the light output without the circuit-level power reducer. (Full system output minus reduced output with a lighting-circuit power reducer divided by the full system output times 100.)
light pollution	An unwanted consequence of outdoor lighting that includes such effects as sky glow, light trespass, and glare.
light power density (LPD)	Sometimes referred to as power density. A measurement of the ratio of light output in an area and the electric power used to produce that light. LPD is determined by dividing the total light output by the total wattage consumed and is measured in lumens per watt.
light trespass	A undesirable condition in which exterior light is cast where it is not wanted.
light-emitting diode (LED)	A solid-state electronic device formed by a junction of P- and N-type semiconductor material that emits light when electric current passes through it. LED commonly refers to either the semiconductor by itself, i.e. the chip, or the entire lamp package including the chip, electrical leads, optics and encasement.
line voltage	The voltage supplied by the electric power infrastructure, typically 110-120 Vac at 60 Hz for homes in North America.
load capacity	The maximum total power that can be connected to an occupancy sensor.
load shedding	The practice of turning off electrical devices during peak energy demand hours to reduce building energy use.
louver	A fixed shield, usually divided into small cells, that is attached to the face of a luminaire to reduce direct glare.
low battery voltage disconnect	Indicates whether or not an exit sign has a circuit that is designed to disconnect the battery after it is discharged. This circuit prevents damage to the battery. Lead acid and lead calcium batteries need this circuit, but nickel cadmium batteries do not.
low-voltage circuit protection	Protection for a ballast's low-voltage control circuit from high voltage spikes. Does not apply to high-voltage controls.
lumen (lm)	A unit measurement of the rate at which a lamp produces light. A lamp's light output rating expresses the total amount of light emitted in all directions per unit time. Ratings of initial light output provided by manufacturers express the total light output after 100 hours of operation.
lumen depreciation	The decrease in lumen output that occurs as a lamp is operated, until failure. Also referred to as lamp lumen depreciation (LLD).
lumen maintenance	The ability of a lamp to retain its light output over time. Greater lumen maintenance means a lamp will remain brighter longer. The opposite of lumen maintenance is lumen depreciation, which represents the reduction of lumen output over time. Lamp lumen depreciation factor (LLD) is commonly used as a multiplier to the initial lumen rating in illuminance calculations to compensate for the lumen depreciation. The LLD factor is a dimensionless value between 0 and 1.
luminaire	A complete lighting unit consisting of a lamp or lamps and the parts designed to distribute the light, to position and protect the lamp(s), and to connect the lamp(s) to the power supply. (Also referred to as fixture.)
luminaire angle	The vertical (altitude) angle used in luminaire photometry to express the direction of the light output being measured. Light coming straight down is at 0° (the nadir).
luminaire efficacy	The ratio of the measured light output of a luminaire to its active power, expressed in lumens per watt (LPW).
luminaire efficiency	The ratio, expressed as a percentage, of the light output of a luminaire to the light output of the luminaire's lamp(s). Luminaire efficiency accounts for the optical and thermal effects that occur within the luminaire under standard test conditions.

luminance	The photometric quantity most closely associated with the perception of brightness, measured in units of luminous intensity (candelas) per unit area (square feet or square meter).
luminance contrast	Luminance contrast quantifies the relative brightness of an object against its background. It can range from zero and one. The closer the luminance contrast is to one, the greater the relative brightness of the object against its background.
luminous flux	Luminous radiant power, measured in lumens. The overall light output of a lamp or luminaire.
luminous intensity	The luminous flux on a small surface centered on and normal to the direction divided by the solid angle (in steradians) that the surface subtends at the source. Luminous intensity can be expressed in candelas or in lumens per steradian.
lux (lx)	A measure of illuminance in lumens per square meter. One lux equals 0.093 footcandle.
MacAdam ellipse	Researcher David L. MacAdam showed that a just noticeable difference (JND) in the colors of two lights placed side-by-side was about three times the standard deviation associated with making color matches between a reference light and a test light (MacAdam 1942, Wyszecki and Stiles 1982). These JNDs form an elliptical pattern of "constant discriminability" in a chromaticity space, centered on the chromaticity of a reference light, known as MacAdam ellipse.
maximum ambient temperature	The maximum ambient temperature for which a compact fluorescent lamp (CFL) product is warranted to achieve rated life.
maximum ballast case temperature	The maximum temperature of the ballast case for which the manufacturer's life rating is valid.
maximum relative light output	Illuminance measured at a fixed distance from the lamps.
mean light output	Light output typically evaluated at 40% of rated lamp life. In combination with initial light output, mean light output may be used to estimate lamp lumen depreciation.
medium bi-pin	A type of connector commonly used on T-8 and T-12 fluorescent lamps. Two small pins protrude from the lamp ends, which are inserted into a socket in the fixture.
mercury vapor (MV) lamp	A high-intensity discharge lamp type that uses mercury as the primary light-producing element. Mercury vapor lamps produce light with a CCT from 3000 to 7000 K. Mercury vapor lamps with clear outer bulbs have CRI values from 15 to 25, whereas phosphor-coated lamps have CRI values from 40 to 55. Mercury vapor lamps are less efficacious than other HID lamp types, typically producing only 30 to 65 LPW, but they have longer lamp lives and lower initial costs than other HID lamp types.
metal halide (MH) lamp	A high-intensity discharge lamp type that uses mercury and several halide additives as light-producing elements. Metal halide lamps have better color properties than other HID lamp types because the different additives produce more visible wavelengths, resulting in a more complete spectrum. Metal halide lamps are available with CCTs from 2300 to 5400 K and with CRI values from 60 to 93. Efficacies of metal halide lamps typically range from 75 to 125 LPW.
metal halide lamp	A high-intensity discharge (HID) lamp that uses mercury and several halide additives as light-producing elements. Metal halide lamps have better color properties than other HID lamp types because the different additives produce light distributed over more visible wavelengths, resulting in a more complete spectrum. Metal halide lamps are available with CCTs from 2300 to 5400 K and with CRI values from 60 to 93. Efficacies of metal halide lamps typically range from 75 to 125 LPW.
metamers	Lights of the same color but of different spectral power distribution.
miniature bi-pin	A type of connector commonly used on T-5 lamps. Similar in design to but smaller than medium bi-pin connectors, it uses two small pins that protrude from the lamp ends and are inserted into a fixture socket.
minimal erythema dose (MED)	The quantity of ultraviolet radiation (expressed in Joules per square meter) required to produce the first perceptible, redness reaction on human skin with clearly defined borders. MED can vary significantly depending on factors such as skin pigmentation.
minimum ambient temperature	The minimum temperature at which a compact fluorescent lamp (CFL) product is warranted to start.
minimum bulb wall temperature (MBWT)	The temperature of the coldest spot on a lamp's bulb wall. MBWT is determined by the ambient temperature, the heat generated within the luminaire, and the luminaire's heat dissipation effectiveness. The coldest spot on a lamp wall is where the mercury vapor tends to condense because pressure is lowest there.
minimum dimmed level	The lowest dimmed level achieved by a ballast, expressed as a percentage of that ballast's maximum light output.
minimum load requirement	The minimum power required for an occupancy sensor to operate properly.
minimum required efficacy	The minimum lamp efficacy required by EPACT, expressed in lumens per watt (LPW).
minimum starting temperature	The minimum ambient temperature at which a ballast will reliably start fluorescent lamps.
monochromatic	For light, consisting of a single wavelength and having a very saturated color.

multitap	A passive distribution component composed of a directional coupler and a splitter with two or more output connections.
nadir	In the lighting discipline, nadir is the angle pointing directly downward from the luminaire, or 0°. Nadir is opposite the zenith.
noncutoff luminaire	IESNA classification that describes a luminaire light distribution in which there is no candela limit on in the zone above maximum candela. (See also cutoff classification and cutoff angle.)
open-circuit voltage	The voltage applied across the output terminals of a ballast when no load is connected. Open-circuit voltage is the voltage applied across a lamp circuit to start the lamp. After starting, the voltage rapidly decreases and stabilizes at the operating voltage.
operating cycle	The frequency with which lamps are cycled on and off.
operating electrode voltage	The voltage that a ballast supplies to a lamp's electrodes.
operating position	The manufacturer-recommended operating position for a lamp.
operating voltage	The voltage a ballast supplies to a lamp's electrodes.
PAR lamp	An incandescent or tungsten-halogen incandescent lamp with a hard glass bulb and an interior reflecting surface, a precisely placed filament, and a lens to control beam spread. The lens is hermetically sealed to the reflector. Metal halide PAR-lamps are also now available.
pendant mounting	A suspension device between a mount and a luminaire.
phase displacement	The extent to which voltage and current waveforms are out of synchronous phase with one another. Current lags or leads voltage, depending on whether the current waveform crosses a reference point after or before the voltage waveform, respectively. Phase displacement can be expressed as a unit of time, as a fraction of the period, or as an angle in degrees with one period corresponding to 360 degrees. When voltage and current are synchronized, phase displacement is zero.
phosphors	Materials used in a light source to produce or modify its spectral emission distribution. In fluorescent and high intensity discharge lamps, the phosphors fluoresce (emit visible light) when excited by ultraviolet radiation produced by mercury vapor inside the lamp when energized by an electric arc. In a light emitting diode, phosphors convert short-wavelength light or ultraviolet radiation produced by a semiconductor die into longer-wavelength light, usually with the goal of producing white illumination.
photon	A small bundle or quantum of electromagnetic energy, including light.
photopic	Vision mediated essentially or exclusively by the cones. It is generally associated with adaptation to a luminance of at least 3.4 cd/m ² .
photosensor	A device used to integrate an electric lighting system with a daylighting system so lights operate only when daylighting is insufficient.
photovoltaic (PV)	Photovoltaic (PV) cells produce electric current from light energy (photons). PV cells are joined to make PV panels.
PN junction	For light emitting diodes, the portion of the device where positive and negative charges combine to produce light.
polarized light	Light whose vibrations are oriented in (or around, for partially polarized light) a specific plane.
position factor	The light output of the lamp in a certain position divided by the light output of the lamp in the base-up position.
positive affect	Relatively mild shifts in current mood in a positive direction.
power	The power used by a device to produce useful work (also called input power or active power). In lighting, it is the system input power for a lamp and ballast or driver combination. Power is typically reported in the SI units of watts.
power factor (PF)	The ratio of active power (in watts) to apparent power (in rms volt-amperes), power factor is a measure of how effectively an electric load converts power into useful work. Power factor (PF) is calculated using the equation $PF = (\text{active power}) / [(\text{rms voltage}) \times (\text{rms current})]$. Phase displacement and current distortion both reduce power factor. A power factor of 0.9 or greater indicates a high power factor ballast.
power line carrier (PLC)	A system that transmits high-frequency (50 to 500 kHz) analog or digital signals via the power lines of a building. These signals control devices such as luminaires or contain voice transmissions such as intercom messages. Some commercial and residential energy management systems also use power line carrier systems.
power quality	The degree to which current and voltage wave forms conform to a sinusoidal shape and are in synchronous phase with each other. Poor power quality results when the wave forms are distorted and/or out of phase and can interfere with data communications, cause inefficient operation or failure of other electrical equipment on the same supply line, and result in excessive current in electrical distribution lines.

power reduction efficiency factor	A measure of the efficiency of a power reducer, representing the reduced light output in percent from a lighting-circuit power reducer divided by the reduced active power in percent from a lighting circuit power reducer.
preheat	A method of starting fluorescent lamps in which the electrodes are heated before a switch opens to allow a starting voltage to be applied across the lamp. With preheat starting, the lamp flashes on and off for a few seconds before staying lit because several starting attempts may be necessary to establish the electric arc across the lamp electrodes. Often, the luminaire's start button must be held down until the lamp lights. Preheat ballasts are less energy efficient than rapid-start or instant-start ballasts.
preheat time	For rapid-start lamps, the time from the onset of lamp current to the lamp arc's striking, during which the lamp electrodes are heated to ease starting.
preheating time	Also referred to as preheat time and lamp preheat time. The length of time that a ballast heats a lamp's electrodes before initiating the lamp arc. Rapid start ballasts preheat a lamp before initiating the arc in order to ease starting. Too short or too long.
primary	Any one of three lights in terms of which a color is specified by giving the amount of each required to match it by additive combination.
prismatic lens	An optical component of a luminaire that is used to distribute the emitted light. It is usually a sheet of plastic with a pattern of pyramid-shaped refracting prisms on one side. Most ceiling-mounted luminaires in commercial buildings use prismatic lenses.
programmed start	Refers to a type of rapid start ballast that optimizes the starting process by waiting until the lamp's electrodes have been heated to apply the starting voltage, thus easing the load to the electrode and extending lamp life. Standard rapid start ballasts heat the electrodes during the starting process to allow quicker starting without flicker.
pulse-width modulation	Operating a light source by very rapidly (faster than can be detected visually) switching it on and off to achieve intermediate values of average light output; the frequency and the duty cycle (percentage of time the source is switched on) are important parameters in the modulation.
R lamp	A common reflector lamp. An incandescent filament or electric discharge lamp in which the sides of the outer blown-glass bulb are coated with a reflecting material so as to direct the light. The light-transmitting region may be clear, frosted, or patterned.
rapid start	A method of starting fluorescent lamps in which the electrodes are heated prior to starting, using a starter that is an integral part of the ballast. Heating the electrodes before starting the lamps reduces the voltage required to strike the electric arc between the electrodes. A rapid-start system starts smoothly, without flashing.
rare-earth phosphors	A group of phosphors containing rare-earth elements. Rare-earth phosphors are used in fluorescent lamps to achieve high efficacy and better color rendering. They produce light in very narrow wavelength bands.
rated average lamp life	Also referred to as lamp rated life. Lamps are tested in controlled settings and the point at which 50% of a given sample burns out is listed as the lamps' rated average lamp life.
rated lamp life	The number of hours at which half of a group of product samples fail. The rated life is a median value of life expectancy; any lamp or group of lamps may vary from the published rated life. Rated life is based on standard test conditions.
rated light output	The sum of the initial rated lamp lumens of the lamp(s) that were supplied with the luminaire.
rated light output from lamp(s)	The sum of the initial rated lamp lumens of the lamp(s) that were supplied with the luminaire.
rated lumen	Also referred to as rated light output from lamp in lumens. Lumen refers to a unit measurement of the rate at which a lamp produces light. A lamp's light output rating expresses the total amount of light emitted in all directions per unit time. Manufacturers rate their lamps' initial light output after 100 hours of operation.
RE70	Designation referring to lamps that use rare-earth phosphors and have color-rendering index values of 70-79.
RE80	Designation referring to lamps that use rare-earth phosphors and have color-rendering index values of 80-89.
RE80 HLO, LL	An RE80 lamp with additional enhancements of high light output (HLO) and/or long life (LL).
RE90	Designation referring to lamps that use rare-earth phosphors and have color-rendering index values equal to or greater than 90.
reactive power	Power that creates no useful work. It results when current is not in phase with voltage. It is calculated using the equation reactive power = $V \times A \times \sin(q)$ where q is the phase displacement angle.
reflectance	A measure of the ability of an object to reflect or absorb light, expressed as a unitless value between 0 and 1. A perfectly dark object has a reflectance of 0, and a perfectly white object has a reflectance of 1.

relative beam diameter (manufacturer)	The normalized beam diameter based on manufacturer-supplied beam angles.
relative beam diameter (NLRIP)	The normalized beam diameter based on NLRIP-measured values.
relative CBCP (manufacturer)	The normalized center beam candlepower based on manufacturer-supplied values.
relative system efficacy	The ratio of relative light output (RLO) to system active power. For each lamp type, relative system efficacy is normalized to the highest value at the maximum light output level, which is assigned a relative system efficacy value of 100%.
restart time	The time required for a lamp to restart, or start, and to return to 90% of its initial light output after the lamp is extinguished. Normally, HID lamps need to cool before they can be restarted.
rms current	Root-mean-square current, a value that quantifies the magnitude of a current that varies with time (as in ac circuits). Rms current is calculated as the square root of the squared values of current over one complete cycle. Rms current delivers the same power to a resistive load as an equivalent steady dc current.
root-mean-square (rms)	The effective average value of a periodic quantity such as an alternating current or voltage wave, calculated by averaging the squared values of the amplitude over one period and taking the square root of that average.
semiconductor	A material whose electrical conductivity is between that of a conductor and an insulator; the conductivity of most semiconductors is temperature dependent.
semicutoff luminaire	IESNA classification that describes a luminaire light distribution in which the candela per 1000 lamp lumens does not numerically exceed 50 (5%) at or above an angle of 90° above nadir, and 200 (20%) at or above a vertical angle of 80° above nadir. This applies to all lateral angles around the luminaire.
sensitivity adjustment	A trim potentiometer (sometimes called a "trim pot") or a set of dip switches used to refine the response function of a photosensor. Some photosensors include a remote trim pot that allows for adjustment at a distance from the photosensor housing.
shielding	Blocking an electrical or magnetic field with a metallic substance. The incident field induces currents in the metallic substance, and these currents induce a field that opposes the incident field. Shielding reduces radiated electromagnetic waves. Electronic components, wires, lamps, and devices can all be shielded.
sky glow	Brightening of the sky caused by outdoor lighting and natural atmospheric and celestial factors.
skylight	A device similar to a window that is placed in a roof, allowing sunlight to enter a structure, thus reducing the need for electrical lighting. Skylights can be used to reduce peak load demand by taking advantage of sunlight during the peak demand time of the day.
sound rating	Magnetic ballasts sometimes produce a humming noise caused by vibration of the magnetic core. Electronic ballasts operate at high frequencies and are usually less noisy. Ballasts are rated from "A" to "F" based on their noise levels. Ratings define the range of ambient sound levels in which people will not notice the ballast noise. The higher the rating, the more noise that will be required to mask the ballast hum.
spectral power distribution (SPD)	A representation of the radiant power emitted by a light source as a function of wavelength.
specular angle	The reflected angle of light striking a surface, which is equal to and in the same plane as the incident angle.
specular reflection	Light incident on a surface that is redirected at the specular angle. Glossy or shiny surfaces exhibit a high degree of specular reflection.
spill light	Light that falls outside of the area intended to be lighted.
standard deviation	A measure of the average distance of a set of data points from their mean. A set of data points that are all close to their mean will have a smaller standard deviation than a set of points that are further from their mean.
starting method	The method a ballast uses to start a lamp. For compact fluorescent lamps (CFLs), ballasts use one of three methods: preheat, instant start, or rapid start. Dimming electronic ballasts use one of these starting methods: rapid start, programmed start, or controlled rapid start.
starting time	The time it takes the lamp to start from the point at which voltage is applied to the lamp until stable operation.
starting voltage	The voltage applied across the lamp during starting.
steradian (sr)	A unit of measure equal to the solid angle subtended at the center of a sphere by an area on the surface of the sphere equal to the square of the sphere radius.
substrate	For light emitting diodes, the material on which the devices are constructed.

supply voltage	The voltage, usually direct, applied by an external source to the circuit of an electrode.
system efficacy	Also referred to as relative system efficacy, system efficacy is a measurement of a system's ability to convert electricity into light. Measured in lumens per watt (LPW), system efficacy is the ratio of the light output (in lumens) to the active power (in watts).
time delay range	For motion sensors, the range of time that may be set for the interval between the last detected motion and the turning off of the lamps.
total harmonic distortion (THD)	A measure of the degree to which a sinusoidal wave shape is distorted by harmonics, with higher values of THD indicating greater distortion.
track head diameter	The size of the luminaire used in a track lighting system.
track luminaire options	Accessories available for track luminaires.
track mounting	For track luminaires, the method by which the track is attached to the ceiling.
transformer	Transformers are electrical devices with no moving parts, which change distribution voltages to higher or lower levels. When used with incandescent or halogen lamps, they typically step 120-V distribution downward to 12V, although 5.5V and 24-V models are also offered.
transients	For an alternating current circuit, a momentary voltage surge, often at amplitudes 10 to 20 times the normal voltage.
tri-level switching	Control of light source intensity at three discrete levels in addition to on to off.
tri-phosphor	A mixture of three phosphors to convert ultraviolet radiation to visible light in fluorescent lamps; each of the phosphors emits light that is blue, green or red in appearance with the combination producing white light.
tri-phosphors	Tri-phosphors are a blend of three narrow-band phosphors (red, blue, and green) that provide improved color rendition and higher light output versus some other types of phosphors.
trim option	A decorative luminaire accessory.
ultrasonic frequency	The frequency at which an ultrasonic sensor operates.
ultraviolet	Any radiant energy within the wavelength range 100 to 400 nanometers is considered ultraviolet radiation (1 nanometer = 1 billionth of a meter, or 1×10^{-9} m).
uniformity	The degree of variation of illuminance over a given plane. Greater uniformity means less variation of illuminance. The uniformity ratio of illuminance is a measure of that variation expressed as either the ratio of the minimum to the maximum illuminance or the ratio of the minimum to the average illuminance.
uplight	Light directed upward at greater than 90° above nadir. The source of uplight can be from a combination of direct uplight and reflected light.
venting	Holes in the reflector assembly of a downlight.
vertical illuminance	The average density of luminous flux incident on a vertical surface, measured in footcandles (fc) or lux (lx). One fc equals 10.76 lx.
visual performance	The quantitative assessment of the performance of a visual task, taking into consideration speed and accuracy.
voltage drop	The difference between the voltages at the transmitting and receiving ends of a feeder, main, or service.
voltage regulation	The change in output voltage that occurs when the load (at a specified power factor) is reduced from rated value to zero, with the primary impressed terminal voltage maintained constant.
wall-washing	The practice of illuminating vertical surfaces, such as walls. Wall-washer luminaires are designed to illuminate vertical surfaces.
warm-up time	The time it takes for a lamp to produce 90% of its initial light output when it is started, unless otherwise indicated.
wavelength	The distance between two corresponding points of a given wave. Wavelengths of light are measured in nanometers (1 nanometer = 1 billionth of a meter, or 1×10^{-9} m).
weight	The weight of a luminaire plus ballast (except for certain track luminaires with separately mounted ballasts, when the weight is that of the lamp and track head only). For modular compact fluorescent lamp (CFL) ballasts, the weight of the ballast without a lamp. For self-ballasted CFLs, "weight" indicates the total product weight.
x-bar	Color matching function x-bar, y-bar, z-bar are used to define the color-matching properties of the CIE

1931 standard observer. In 1931, CIE defined the color-matching functions \bar{x} -bar, \bar{y} -bar, \bar{z} -bar in the wavelength range from 380nm to 780 nm at wavelength intervals of 5nm.

zenith

In the lighting discipline, zenith is the angle pointing directly upward from the luminaire, or 180°. Zenith is opposite nadir. In astronomical usage, zenith is the highest point in the sky, directly above the observation point.

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EXHIBIT E

Thomas Paciorkowski

From: Lighting Institute Info (GE Consumer & Industrial) [LightingInstituteInfo@ge.com]
Sent: Thursday, July 02, 2009 9:49 AM
To: Thomas Paciorkowski
Subject: RE: Lighting Product Information or Literature

Dear Mr. Paciorkowski,

Thank you for contacting GE Lighting. I am happy to assist you.

We appreciate your interest in our Company and our products. In response to your question, typically, the filament type of bulb (Incandescent & Halogen) maintains its light output over its lifetime.

Please feel free to visit us at www.gelighting.com for lighting resources available online. Choose "Commercial Products" on the home page. The top navigation bar offers Education/Resources, and Lighting Applications sections.

For additional information, you may also want to check "The Illuminating Engineering Society of North America" (IESNA) website at www.iesna.org.

Please let us know if we can be of any further assistance.

Regards,

Chris

GE Lighting Internet Response Team
GE Lighting - 1-800-GELIGHT (1-800-435-4448) Monday through Friday, 8:00 am - 6:00 pm EDT

-----Original Message-----

From: tpaciorkowski@eichenlevinson.com
[<mailto:tpaciorkowski@eichenlevinson.com>]
Sent: Monday, June 15, 2009 1:33 PM
To: Lighting Institute Info (GE Consumer & Industrial)
Subject: Lighting Product Information or Literature

Enames : Infolighting@ge.com
Mails subject : Lighting Product Information or Literature
First Name : Tom
Last Name : Paciorkowski
Street Address : RedactedRedacted .
Street Address2 :
City : Redacted
State : Re
Zip Code : Redacted
Country : RedactedRedacted
Phone : Redacted
Fax :
EMail Address : tpaciorkowski@eichenlevinson.com

Product Type : Halogen
Product Code :
Product ID :
Topic : Technical specs
Comments : Does the light output of a halogen bulb
decrease over time, or does it maintain its brightness over its lifespan?

EXHIBIT F

An Iodine Incandescent Lamp with Virtually 100 Per Cent Lumen Maintenance

By E. G. ZUBLER
F. A. MOSBY

A SURVEY of the patent literature indicates that in 1882 a patent (No. 254,780) was issued for the inclusion of a small quantity of Cl_2 in a carbon filament vacuum lamp. Since then, a series of patents have appeared covering the use of I_2 , Br_2 , Cl_2 and mixtures thereof in both incandescent and discharge lamps. It is interesting to note that early patents proposed that the halogen reduced blackening during operation by reacting with the evaporated W to form a more transparent halide layer on the bulb wall. In 1923, a patent (No. 1,552,128) was issued for the inclusion of an alkali halide which supposedly reacted with impurities such as Ni and Fe on the bulb wall to form transparent halides, and reacted with the evaporated W, returning it to the filament in a regenerative cycle.

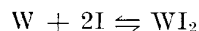
Our present efforts were initiated during the developmental work on the tubular quartz heat lamp. Small quantities of I_2 , added to the usual Ar filling gas, were found to be very efficacious in preventing blackening during normal and over-voltage operation. This work led to the discovery of the necessity for correlating certain critical relationships in order to achieve successful operation of the regenerative cycle.

Iodine Cycle

In general, I_2 is being used in an incandescent lamp to prevent blackening and enhance life by re-depositing evaporated W on the filament. During normal operation of an incandescent lamp, W is transferred from the filament to the wall by normal evaporation and diffusion or via the water cycle.¹ I atoms produced by the pyrolysis of molecular I_2 in the vicinity of the filament diffuse to the wall and under the proper conditions react with the adsorbed W, forming a volatile WI_2 which diffuses to the filament. The WI_2 is decomposed on the filament, resulting in the deposition of the W on the filament and the production of I atoms which then diffuse to the wall to repeat the cycle.

This paper will describe the theory and operation of a new type of incandescent lamp which employs iodine in a regenerative process in which evaporated tungsten (W) is re-deposited on the filament, resulting in approximately 100 per cent lumen maintenance and increased life. While the concept of using a halogen such as chlorine (Cl_2), bromine (Br_2) or iodine (I_2) in a lamp to prevent blackening is not novel, the difficulties associated with the regenerative process have previously precluded its practice. For the first time these difficulties have been overcome and a practical lamp employing iodine in a regenerative cycle can be produced.

Consequently, the iodine cycle depends on the reaction:



where the forward reaction predominates at the wall while the reverse reaction predominates at the higher temperatures of the filament. WI_2 may also be formed in the gas phase as a result of a reaction between W(g) and I atoms (or I_2) with an inert gas molecule removing the excess energy. The relative amounts of WI_2 formed in the gas phase and on the wall are not known. Thermodynamic considerations indicate that the WI_2 is decomposed on filament rather than in the gas phase in the vicinity of the filament. The surface decomposition of the WI_2 is attested experimentally by the success of the I_2 cycle in coiled-coil filament lamps.

The iodine cycle has been extensively studied in the developmental lamp shown in Fig. 1. This particular lamp is a nominal 500-watt, 120-volt tubular, quartz lamp, 10 mm in diameter and 95 mm in length, containing 600 mm of Ar and approximately 1μ mole of I_2 which, if the I_2 were completely vaporized at room temperature, would give a partial pressure of approximately 4.5 mm. The filament operated at 3000K and the wall temperature was approximately 600C. This developmental lamp contains a coiled W filament, spiral W supports, a

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHORS: General Electric Co., Cleveland, Ohio. Accepted by the Papers Committee as a Transaction of the I.E.S.

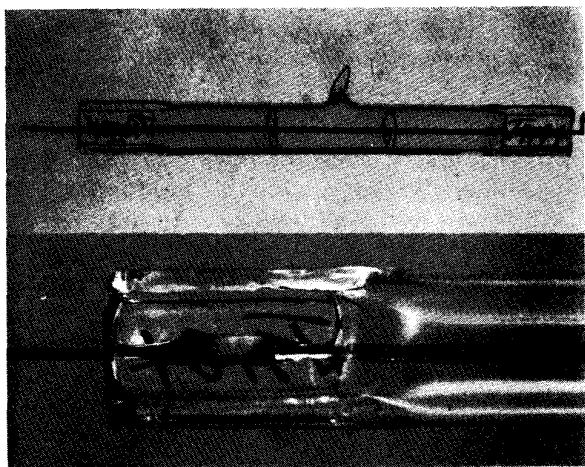


Figure 1. A 500-watt quartz iodine lamp and an enlargement of the pinch seal.

W inner lead welded to Mo foil and an Mo outer lead. With the successful operation of the I_2 cycle, the developmental lamps showed no blackening during operation, *i.e.*, with a filament temperature of approximately 3000K, and most lamps had 100 per cent of initial lumens at the end of life. A typical lamp at burnout is shown in Fig. 2. Since W was being returned to the filament, the life was increased and consequently a higher filament temperature was possible at the same life in the absence of I_2 .

The remarkable efficacy of the I_2 cycle in removing adsorbed W from the surface of a quartz bulb is shown in Fig. 3. The top photograph shows a lamp that was blackened by operating the filament at a high temperature under vacuum. The lamp was then filled with the desired I_2 -Ar mixture and sealed off. Below, is the same lamp after 60 seconds of normal operation. The W was almost completely removed from the wall in 30 seconds.

Wall Temperature Requirements

It has been found that the I_2 cycle will operate successfully with the bulb wall temperature in the range of approximately 250-1200C. Ordinarily, the reaction between W (solid) and I_2 requires a temperature of 700C.⁴ The fact that the cycle does

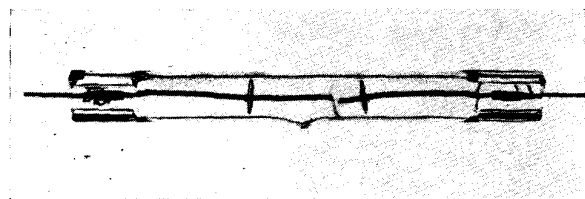


Figure 2. A 500-watt quartz iodine lamp at the end of life—870 hours at 26 lumens per watt.

operate with the wall temperature considerably below 700C indicates that the reaction occurs between W and I atoms (as opposed to molecular I_2), produced by the pyrolysis of molecular I_2 near the filament. The reaction between the adsorbed W and I atoms is primarily dependent on the availability of I atoms at the wall, while wall temperature is relatively unimportant. The lower limit of the bulb wall temperature is determined by the desorption of the WI_2 . If the bulb wall temperature is below this limit, a brown deposit of WI_2 is formed and the cycle is interrupted, resulting in subsequent blackening. The upper limit is determined by the stability of the WI_2 molecule on the wall. At high temperatures, the reverse reaction, $WI_2 \rightarrow W + 2I$ will be favored and the W will not be removed from the wall. This fact is important in considering the attack of the supports and leads by the atomic I with the formation of WI_2 . In the developmental lamp shown, the supports operated at a considerably higher temperature than the wall and as a consequence, the iodine did not transfer W from the support to the filament. If this undesirable condition did exist, not only would the supports be attacked and eventually destroyed but excessive W would be deposited on the filament, resulting in whisker growth and the shorting of adjacent filament turns.

Filament Temperature Requirements

The minimum filament temperature required for the decomposition of the WI_2 is indicated by an examination of one of the W supports from a developmental lamp, shown in Fig. 4. During normal operation of the lamp, W was deposited on the support near the filament and a certain distance from the filament. The point at which the deposition of

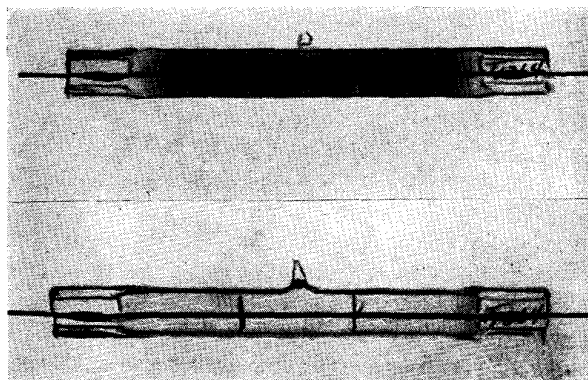


Figure 3. Removal of evaporated W from the bulb wall by iodine cycle. Lamp at top—blackened under vacuum prior to filling; at bottom—same lamp after 60 seconds of normal operation.

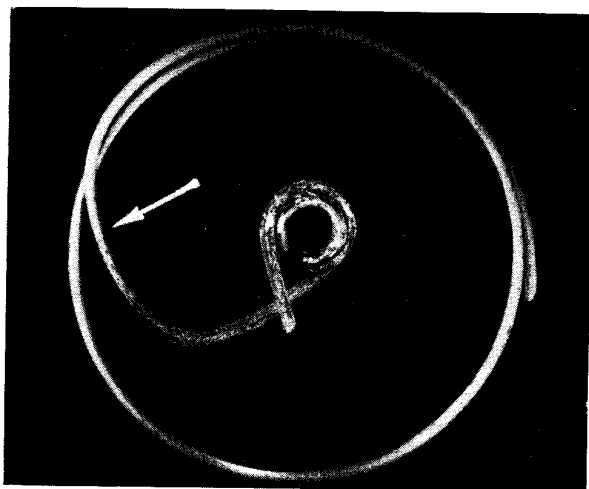


Figure 4. Deposition of W on a support by iodine cycle. Arrow indicates point at which deposition ceased.

W ceased, indicated by the arrow in Fig. 4, was determined by microscopic examination. The temperature of this point on the support was determined in several identical lamps with an optical pyrometer. The average temperature obtained, assumed to be equivalent to the minimum filament temperature required, was well below 2000C, which was substantially below the normal operating temperature of incandescent lamp filaments. However, if the I_2 cycle were to be used in discharge lamps to return evaporated or sputtered metal to the electrodes, this temperature limit could be of very considerable importance.

Iodine Concentration

A priori, the I_2 concentration should be minimized due to the strong absorption of visible radiation by the I_2 . Aside from this consideration, there appeared to be no upper limit for the successful operation of the cycle. The lower limit was difficult to establish due to the presence of varying trace quantities of metallic impurities in the developmental lamps which formed stable iodides in the cooler sections (corners) of the lamp, resulting in a depletion of the I_2 concentration. The concentration of I_2 studied was in the range 0.01 to 1.0 μ moles/cc. with 0.2-0.3 μ moles/cc. employed in the majority of lamps. This concentration, which imparted a distinct pink color to a lamp when the I_2 was vaporized at slightly elevated temperatures ($>50C$), was sufficiently low so that there was no measurable loss of visible radiation by adsorption and sufficiently high so that the usual trace quantities of impurities encountered did not appreciably deplete the I_2 concentration by the formation of stable iodides.

Inert Gas

While evaporated W could be returned to the filament by the I_2 cycle in a vacuum lamp, an inert gas such as Ar, Kr or Xe (600-6000 mm.) was employed in the developmental lamps to prevent arcing and also to decrease the rate of evaporation of W. It was found that if the rate of return of W to the filament were large, whisker formation, pronounced crystal growth on the filament surface and preferential deposition of W on the cooler areas of the filament in the vicinity of the supports and leads was observed. Consequently, it was desirable to minimize the rate of transfer of W to obtain maximum life. While most of the developmental lamps were filled with 600 mm of Ar, there was a tendency for the lamps to arc at the end of life. Due to the high current surge during the arc, the Mo foil in the pinch seal frequently ruptured and the lamp exploded. This situation was rectified either by an external fuse or by increasing the Ar pressure. With an increase in Ar pressure, there was also a considerable increase in life at the same efficiency. These small diameter tubular lamps operate inside the so-called Langmuir sheath² where heat loss is due solely to conduction and is independent of pressure in this range. Consequently, an increase in inert gas pressure resulted in an increase in life by decreasing the rate of evaporation of W from the filament while the wattage, filament temperature and efficiency remained constant.

The I_2 cycle can also operate under certain conditions in the presence of N_2 which is important in certain lamp construction where close spacings present arcing problems. No evidence has been found for compound formation between the N_2 and I_2 (or I), e.g., NI_3 , during operation of these developmental lamps.

Difficulties

(1) In small diameter tubular lamps (6-12 mm o.d.) of the 500-watt variety, a thermal diffusion separation³ of the I_2 and inert gas occurred when the lamp was operated vertically or even several degrees off a horizontal position, resulting in the heavier gas, i.e., the I_2 being concentrated at the bottom of the lamp and the lighter inert gas at the top. This thermal diffusion separation depleted the I_2 concentration at the top of the lamp and blackening resulted. In small diameter 500-watt lamps, the separation which, in general, was a function of temperature gradient and length was unfortunately efficient and necessitated horizontal operation. However, in larger diameter 500-watt lamps (20-35 mm o.d.) turbulent convection currents were operative and promoted remixing so that the sep-

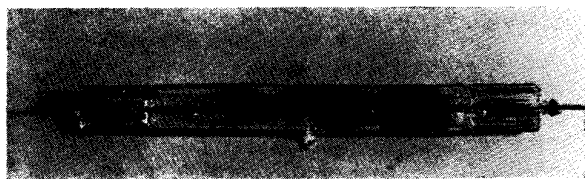


Figure 5. Blackening due to small quantities of impurities in horizontally-operated lamp.

aration did not occur and the lamps could be operated in any position.

(2) It has been found that small quantities of certain materials, *e.g.*, Al, Ni and Hg, interfered with the successful operation of the I_2 cycle and blackening resulted even in the presence of sufficient I_2 . This blackening, shown in Fig. 5, occurred on specific areas of the bulb wall. While blackening of this type usually occurred early in life with no apparent effect on life, it has been observed to occur at any time during life. While the exact cause of this type of blackening has not been established, it is believed to be the result of an accumulation of impurities and a specific surface condition of the bulb wall in certain areas.

(3) Due to the highly reactive nature of the I_2 vapor at elevated temperatures, it was not possible to employ any of the usual getters in the developmental lamps to remove H_2O vapor or H_2 present initially or released from the quartz during operation. Either the I_2 and the getter reacted to form a stable iodide in the cooler areas of the lamp, resulting in a depletion of the I_2 and subsequent blackening, or else the getter material interfered with the formation of WI_2 on the bulb wall, resulting in blackening in the presence of sufficient I_2 . While the I_2 cycle operated successfully in the presence of the H_2O cycle,¹ resulting in a clean lamp throughout life, the life of the lamp was considerably shortened due to H_2O cycle activity. Consequently, it was necessary to minimize the H_2O cycle activity by a good bake-out of the lamp prior to filling and then employing thoroughly dried I_2 and inert gas to insure long life.

Design Features

Lamps made to operate with the iodine cycle have not only shown an extremely high lumen maintenance, but also have other outstanding features which are direct results of meeting the essential requirements for successful operation. As previously indicated, a minimum bulb wall temperature of about 250C is required for reliable performance. This fact dictated the use of either Pyrex, quartz or Vycor as a bulb and lamps were made to operate successfully in each of these materials. All lamps

discussed in this paper were made from tubular quartz or Vycor because of their higher melting points and very good resistance to thermal shock. If a bulb wall temperature of approximately 250C or greater is to be maintained, the filament must be located comparatively close to the bulb wall. A tubular bulb allows us to achieve this temperature without large variations between temperatures at the hottest and coolest portion of the bulb on which the cycle is functioning. The tubular construction also shows other advantages when the lamp is mounted in a luminaire.⁵

Interference with the iodine cycle caused by metals other than tungsten necessitated making lamps without filament supports or with supports of tungsten, and also indicated that the portion of the lead projecting into the lamp must be tungsten. The basic construction of an iodine lamp is shown in Fig. 1. The leads are two piece molybdenum-tungsten and the supports are tungsten wire. This design meets the temperature and material requirements and also permits an increase in operating voltages because of the double-ended construction. By increasing the length of the coil, a 10,500-watt argon-filled iodine lamp which successfully operates on 2400 volts has been made.

Fig. 6 shows some of the developmental lighting lamps that have been made in which the iodine cycle functions properly. From top to bottom, these lamps are rated at 45-, 100-, 150-, 200-, 500- and 1500-watts. They range in length from $1\frac{5}{8}$ to 10 inches, and from $\frac{5}{16}$ to $\frac{1}{2}$ an inch in diameter. Operating voltage for the group is 120 volts or less, with the exception of the 1500-watt lamp which operates at 277 volts. One obvious advantage of this

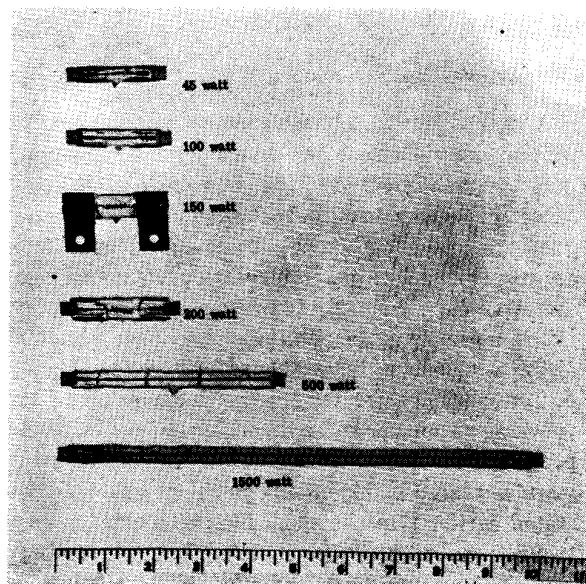


Figure 6. Developmental quartz iodine lamps.

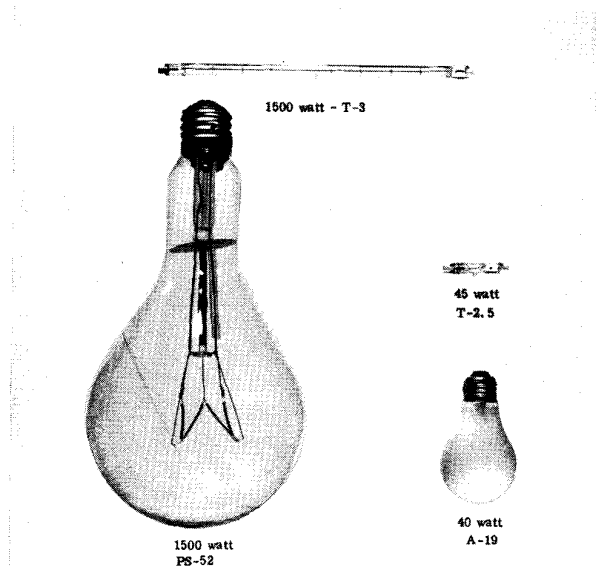


Figure 7. Size comparison of quartz iodine lamps with standard lamps of equal or near-equal wattage.

design is the size reduction it has achieved. In Fig. 7, a comparison of the size of the 45- and 1500-watt iodine lamps is made with that of standard 40- and 1500-watt lamps. The volume of the 45-watt lamp is 1.4 per cent of that of the 40-watt A19 and the 1500-watt volume is .55 per cent of that of the PS52 lamp. The remarkable size reduction is further evidenced by the fact that all of the lamps shown in Fig. 6, which represent a combined total of 2495 watts, occupy less volume than a 25-watt household lamp. Smaller size also means better positioning of the light source in a reflector or luminaire, enabling us to obtain beam patterns heretofore unobtainable.⁵

Operating Characteristics

A unique and favorable characteristic of the tubular lamp is that its lumen output and watts for a given filament are independent of fill gas pressure from a few hundred millimeters to as high a pressure as the bulb will contain. As is commonly known, in the general lighting lamp thermal losses are due to convection currents and conduction. Convection currents passing over the filament reduce its operating temperature and lower its lumen output, while increasing its watts. The effect of convection currents is changed with changes in fill gas pressure, thus, initial lumen and watts rating in a standard lamp is dependent on fill pressure. It was stated earlier that the small diameter bulb contains the fill gas within the so-called Langmuir sheath during lamp operation and convection currents are non-existent. Thermal losses are then due only to

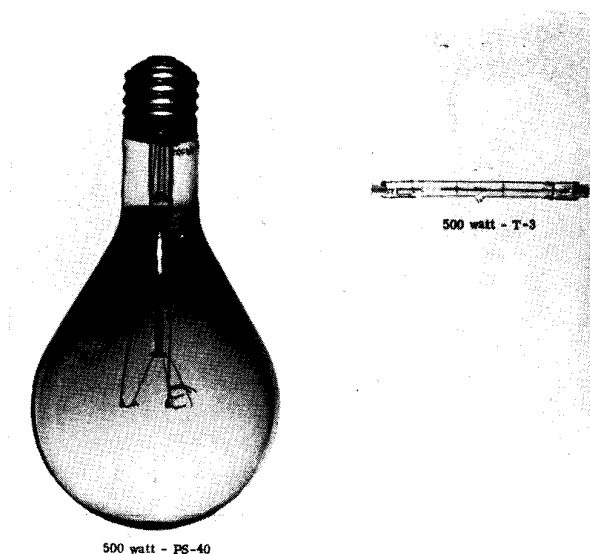


Figure 8. 500-watt standard lamp and 500-watt quartz iodine lamp after failure.

conduction and these losses are independent of gas pressure above a few hundred millimeters. Another favorable result of placing the filament in a small diameter bulb is that of obtaining a higher operating pressure than is obtained in the standard lamp for the same fill pressure. A standard 1000-hour, 500-watt, 19.8-lumen per watt lamp is filled with 600 millimeters of gas and operates at approximately 800 millimeters. The 500-watt filament, when placed in an iodine lamp of the tubular design which is filled with 600 millimeters of gas, will operate at approximately 1800 millimeters. An increase in operating pressure, plus the complete absence of convection currents, enables us to increase the efficacy of the filament to 21 lumens per watt and obtain a 2000-hour life. One more example of gain in efficiency is shown in the comparison of a 1500-watt, 275-volt lamp and a 1500-watt, 277-volt iodine lamp. The standard lamp operates at 17.5 lumens per watt for 1000 hours, while the iodine lamp operates at 22 lumens per watt for 2000 hours.

Lumen maintenance, by far the outstanding feature of this lamp, has ranged from 96-101 per cent on constant voltage lamps at 99 per cent life. These figures are quite remarkable when compared with those of the 500-watt general lighting lamp, whose lumen maintenance is 86 per cent at 70 per cent design life, and the 1500-watt lamp, whose lumen maintenance is 78 per cent at 70 per cent design life. Although figures are not available, it can be seen that the comparison would be even more astounding if the standard lamps were rated at 99 per cent design life. Fig. 8 shows a 500-watt stand-

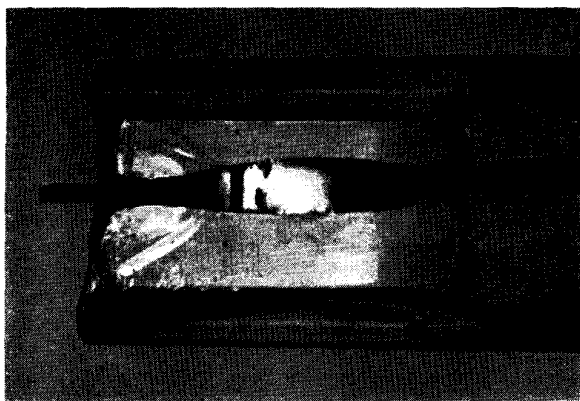


Figure 9. Typical failure pattern on overheated seals. Seal has not yet failed.

ard lamp and a 500-watt iodine lamp after burn-out. The percentage of lumen maintenance quoted for the iodine lamp has been measured on all constant voltage lamps, regardless of wattage.

The iodine lamp as designed, in comparison with a presently-made incandescent lamp of equal wattage, offers an incandescent light source that is drastically reduced in size, with ratings independent of fill gas pressure. Its total lumen output can be increased while maintaining equal life, it can be operated at higher voltages and it maintains 96-101 per cent lumen output until burnout.

Operating Limitations

As is true in other lamps, precautions must be taken with the iodine lamp if it is to give the expected service. We have said that wall temperatures below approximately 250C were too low for reliable cycle operation; therefore, these lamps cannot be operated in a cooling atmosphere. Operation under water or in stiff drafts without a protective covering is not feasible. However, the lamps do perform satisfactorily under normal conditions and applications since the wall temperatures are high enough (500-600C) to maintain adequately the specified minimum. One other temperature limit which it has been necessary to specify is that of the seal. This limitation applies to the developmental lamp construction and is not necessarily a feature of all iodine lamps. Fig. 9 shows the type of failure occurring with overheated seals. Temperatures in excess of 350C, measured on the quartz directly over the center of the molybdenum foil, are detrimental to lamp life. If operated above this figure, oxidation of the foil is rapid enough to puncture the seal and leakage occurs. Lamps placed in evacuated chambers or chambers containing a non-oxygen gas have only the current carrying capacity of the foil as a limitation.

Gas separation, which has been fully explained, was found to be quite pronounced in the longer lamps. The 500-watt and the 1500-watt lamps must not be positioned more than four degrees from a horizontal plane if sufficient iodine is to remain in the high end of the lamp for efficient cycle operation. In the lower wattage lamps the gas separation is not so apparent and these lamps have been operated successfully in a vertical position.

The last precaution that we must indicate is one that is no new, nor limited to the iodine lamp. A fact that many of us may not be aware of is that all high-wattage, argon-filled incandescent lamps are internally fused to protect them against arcing. The common cause of arcing is the failure of the filament at or near the peak of inrush current when the lamp is energized. If not arrested, the arc may cause rupture of the bulb. As presently made, the iodine lamps do not contain an internal fuse and therefore the high-wattage lamps must be externally fused to protect against this type of failure.

Applications

A discussion of the iodine lamp would not be complete without mention of possible or actual applications. It should be noted, however, that these lamps are in a developmental stage and are not presently mass produced. A broad answer to the question of what applications are the lamps suited for is that they can be used in any application that now uses incandescent lamps so long as the required conditions of temperature and position are met. Some specific possible applications would be street lighting, floodlighting of outdoor areas, display window lighting, and illumination for movie making and television. Miniaturization is a prime factor in these applications. To date, four types of iodine lamps are being used in actual applications; only one type has developed to the point of supplying lamps in small quantities. The 45- and 200-watt lamps are being tested for possible use in runway illumination and the 1500-watt lamp is being used to successfully grow algae in underwater and space travel research. The 150-watt lamp has been flight tested and is being used as a wing tip marker on high speed aircraft. While there are many possible applications, the ones mentioned are those in which this lamp may find initial usage; small size and nearly constant lumen output are features which we feel certain will guide it into numerous others.

Acknowledgement

The authors wish to acknowledge their indebtedness to A. Foote, Large Lamp Department, for his guidance and assistance during this work.

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5. Discussed in Paugh, R. L. and Allen, C. J.: "Quartz Lighting Lamp Applications," *ILLUMINATING ENGINEERING*, Vol. LIV, No. 12, pp. 741-748 (December 1959).

DISCUSSION

W. G. MATHESON:* The work reported in this paper deals with results obtained using tubular envelopes. Should one assume that no work has been done on globular envelopes or that the results obtained were unsatisfactory? The necessity of external fusing is not desirable. Also, the precise positioning with respect to the horizontal involves new fixture designs. In fact, it is likely to require extensive fixture replacement with a new design in order to accommodate the proper fuse protection and a satisfactory light distribution pattern.

The authors have indicated a high degree of success in controlling the redeposition of the evaporated tungsten on the filament. We have made tests which indicate that this control is critical due to bulb and filament temperature variations.

A. W. WEEKS:** I would anticipate considerable difficulty in controlling the exacting manufacturing processes required, but undoubtedly these can be met. The following questions have occurred to me:

Is it possible to "coil up" the longer tubular lamps, such as the 1500-watt, so that spotlighting applications would be furthered?

Under the paragraph "Application," the authors say that requirements of temperature and positioning must be met. They then say that the 150-watt lamp has been flight-tested as a wing tip marker. This application does not seem to meet requirements of temperature and positioning.

G. A. FREEMAN:† The accomplishment of a practical lamp with 100 per cent lumen maintenance, as described in this paper, is indeed a milestone of lamp improvement. The function of the reaction between halogen gases, iodine, chlorine, etc., with tungsten to remove tungsten blackening

from a lamp bulb is not new, but to control it for practical use is new.

This is interesting particularly to lamp development engineers who have experimented with iodine or chlorine in the gas filling of incandescent lamps and then set it aside after finding out the requirements for successful operation. The authors have been quite conscientious in pointing out the problems.

Most experimenters have considered the more conventional forms of incandescent lamps where ordinary lamp leads are chemically attacked by the iodine vapor and the minimum temperature requirement of 250C-300C is difficult to achieve. Potential gain in intrinsic quality was not enough incentive to overcome practical limitations.

The tubular quartz lamp with only tungsten parts appears to meet the requirements with fewer practical limitations. Whether the gain in intrinsic quality comes at too high a penalty in light source shape, in limited operating position and in production cost and dependability where trace quantities of impurities would be ruinous remains to be seen. The authors are to be commended on their development which appears to have attained the necessary degree of practicality.

E. G. ZÜBLER AND F. A. MOSBY:* In reply to Mr. Matheson we have found that the iodine cycle does not function satisfactorily in globular envelopes such as the standard "A" bulb shape. There are two reasons for this. First, temperature variations are such that the cycle does not operate on all portions of the bulb, and second, manufacturing methods for the usual "A"-shaped lamp do not permit all tungsten parts internally. Also, the fact that a minimum wall temperature of 250C is required would prohibit its use in present standard sockets.

In answer to Mr. Weeks' question, there has been no attempt to coil up the 1500-watt lamp since a shorter lamp could be obtained by using a coiled-coil filament. The 500 and 1500-watt lamps are not now offered with coiled-coil filaments because of support problems.

As stated in the paper, the lower wattage lamps are not restricted to a horizontal burning position and the 150-watt lamp falls in this group. Temperature specifications for the wing tip application are above the 350C seal limit. However, the aircraft manufacturer and his customers are fully aware of the seal limitation and still choose to use the iodine lamp because they have found no other which will perform as well.

*Sylvania Lighting Products, Salem, Mass.

**Champion Lamp Works, Lynn, Mass.

†Westinghouse Electric Corp., Bloomfield, N. J.

*Authors.

Annual Index to IE

The Index to 1959, to be published as Section II of the January 1960 issue of *ILLUMINATING ENGINEERING*, includes subject and author indexes and, in addition, business addresses, where available, for IES officers and committee personnel for 1957-1958 and 1958-1959.

EXHIBIT G

ABOUT IEEE SPECTRUM

IEEE Spectrum magazine is the flagship publication of the IEEE, the world's largest professional technology association. It is a monthly magazine for technology innovators, business leaders, and the intellectually curious. Spectrum explores future technology trends and the impact of those trends on society and business.

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EXHIBIT H



The world's largest professional association for the advancement of technology

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History of IEEE

IEEE, an association dedicated to advancing innovation and technological excellence for the benefit of humanity, is the world's largest technical professional society. It is designed to serve professionals involved in all aspects of the electrical, electronic and computing fields and related areas of science and technology that underlie modern civilization.

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IEEE's roots, however, go back to 1884 when electricity was just beginning to become a major force in society. There was one major established electrical industry, the telegraph, which—beginning in the 1840s—had come to connect the world with a communications system faster than the speed of transportation. A second major area had only barely gotten underway—electric power and light, originating in Thomas Edison's inventions and his pioneering Pearl Street Station in New York.

Meaning of "I-E-E-E"

IEEE, pronounced "Eye-triple-E", stands for the Institute of Electrical and Electronics Engineers. The association is chartered under this name and it is the full legal name.

However, as the world's largest technical professional association, IEEE's membership has long been composed of engineers, scientists, and allied professionals. These include computer scientists, software developers, information technology professionals, physicists, medical doctors, and many others in addition to our electrical and electronics engineering core. For this reason the organization no longer goes by the full name, except on legal business documents, and is referred to simply as IEEE.

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Foundation of the AIEE

In the spring of 1884, a small group of individuals in the electrical professions met in New York. They formed a new organization to support professionals in their nascent field and to aid them in their efforts to apply innovation for the betterment of humanity—the American Institute of Electrical Engineers, or AIEE for short. That October the AIEE held its first technical meeting in Philadelphia, Pa. Many early leaders, such as founding President Norvin Green of Western Union, came from telegraphy.

Others, such as Thomas Edison, came from power, while Alexander Graham Bell represented the newer telephone industry. As electric power spread rapidly across the land—enhanced by innovations such as Nikola Tesla's AC Induction Motor, long distance AC transmission and large-scale power plants, and commercialized by industries such as Westinghouse and General Electric—the AIEE became increasingly focused on electrical power and its ability to change people's lives through the unprecedented products and services it could deliver. There was a secondary focus on wired communication, both the telegraph and the telephone. Through technical meetings, publications, and promotion of standards, the AIEE led the growth of the electrical engineering profession, while through local sections and student branches, it brought its benefits to engineers in widespread places.

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Foundation of the IRE

A new industry arose beginning with Guglielmo Marconi's wireless telegraphy experiments at the turn of the century. What was originally called "wireless" became radio with the electrical amplification possibilities inherent in the vacuum tubes which evolved from John Fleming's diode and Lee de Forest's triode. With the new industry came a new society in 1912, the Institute of Radio Engineers.

The IRE was modeled on the AIEE, but was devoted to radio, and then increasingly to electronics. It, too, furthered its profession by linking its members through publications, standards and conferences, and encouraging them to advance their industries by promoting innovation and excellence in the

emerging new products and services.

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The Societies converge and merge

Through the help of leadership from the two societies, and with the applications of its members' innovations to industry, electricity wove its way—decade by decade—more deeply into every corner of life—television, radar, transistors, computers. Increasingly, the interests of the societies overlapped.

Membership in both societies grew, but beginning in the 1940s, the IRE grew faster and in 1957 became the larger group. On 1 January 1963, The AIEE and the IRE merged to form the Institute of Electrical and Electronics Engineers, or IEEE. At its formation, the IEEE had 150,000 members, 140,000 of whom were in the United States.

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Growth and globalization

Over the decades that followed, with IEEE's continued leadership, the societal roles of the technologies under its aegis continued to spread across the world, and reach into more and more areas of people's lives. The professional groups and technical boards of the predecessor institutions evolved into IEEE Societies. By the early 21st Century, IEEE served its members and their interests with 38 societies; 130 journals, transactions and magazines; more 300 conferences annually; and 900 active standards.

Since that time, computers evolved from massive mainframes to desktop appliances to portable devices, all part of a global network connected by satellites and then by fiber optics. IEEE's fields of interest expanded well beyond electrical/electronic engineering and computing into areas such as micro- and nanotechnology, ultrasonics, bioengineering, robotics, electronic materials, and many others. Electronics became ubiquitous—from jet cockpits to industrial robots to medical imaging.

As technologies and the industries that developed them increasingly transcended national boundaries, IEEE kept pace, becoming a truly global institution which used the innovations of the practitioners it represented in order to enhance its own excellence in delivering products and services to members, industries, and the public at large. Publications and educational programs were delivered online, as were member services such as renewal and elections. By 2010, IEEE had over 395,000 members in 160 countries. Through its worldwide network of geographical units, publications, web services, and conferences, IEEE remains the world's largest technical professional association.

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EXHIBIT I

FEATURE

Requiem for the Incandescent Lightbulb

A look back at a century of light

By BRIAN BOWERS / APRIL 2011



Illustration: Serge Bloch

Before it could flourish, electric lighting had to defeat an entrenched competitor in many towns—gas. In the mid- and late 19th century, gaslight simply meant a bare gas flame, so the electric lamp, which produced no smoke, was a clear winner. But the gas industry didn't give up easily; it developed the gas mantle during the 1880s, then greatly improved it in the 1890s. This fine mesh, made mainly of thorium oxide, became incandescent when heated by a gas flame smaller than what had been used in previous generations of gas lamps. This technology also allowed the industry to change the composition of its gas so that the flames produced more heat and less light—and less smoke. The gas mantle turned out to be a cheaper source of light than the carbon filament lamp. Score round one to gas.

Starting around 1899, electricity answered the gas mantle with the metal filament, which could be operated at a hotter temperature,

and therefore more efficiently, than a carbon filament. Developers tried several different filament materials. Osmium, tantalum, and tungsten have the highest melting points in the metals family but differ in their malleability. Initially, lamp manufacturers used osmium, also seen in the tips of fountain pens and in some heavy-duty electrical contacts, and tantalum, which was first isolated in 1902. Tungsten was attractive because it has the highest melting point of all metals—just over 3400 °C. But its brittleness stymied developers who were trying to draw it into a thin wire. Then Alexander Just and Franz Hanaman, working in Vienna and Budapest, found that they could make tungsten filaments by mixing tungsten powder with a binder and then drawing that mixture into a wire and sintering it—that is, heating it until the particles adhere but do not melt. Hugo Hirst, of the (British) General Electric Co., working with Just and Hanaman, began producing tungsten lamps in 1909, in a factory in West London. William Coolidge, of the (U.S.) General Electric Co., found that if he compressed tungsten powder and hammered it, he could draw it into a wire without using any binder, which was a simpler process. (There was no connection between the two General Electric companies.) Thus was born, in 1911, the drawn-tungsten filament incandescent lamp. It continues to be the standard in incandescent bulbs to this day, 100 years later.

In early tungsten lamps, the filaments sat in near vacuums, but it turned out that a little nitrogen or argon reduced the evaporation of the metal and prolonged the filament's life. The problem was that the gas also cooled the filament, making the lamp less efficient. Winding the filament in a coil reduced the cooling, and winding the coil itself into a coil, a technique developed in the early 1930s, worked even better. And that coiled-coil filament design has never been superseded.

In 1959, General Electric (U.S.) refined the filament lamp one more time. Its researchers sealed a tungsten filament into a compact bulb containing an inert gas and a small amount of a halogen, usually iodine or bromine. (The halogens are a group of elements that react very readily and energetically with other substances.)

In a halogen bulb, the halogen gas combines with the minute particles of tungsten that evaporate from the filament, which in ordinary incandescent lamps are deposited mostly on the inner surface of the bulb and over time gradually dim the light output. The tungsten halide that forms moves around as a gas and then, when it nears the hot filament, breaks down, redepositing the tungsten back onto the filament and releasing the halogen to repeat the process.

This halogen cycle keeps the bulb clean and the light output almost constant over the life of the bulb. The bulb temperature must be higher than in conventional incandescent lamps, too high for glass at the time, so the bulb was initially made of quartz. Because the first halogen lamps used iodine as the halogen, they were known as "quartz iodine" lamps. Later, bromine replaced iodine, higher-melting-point glass replaced the expensive quartz, and the lamps became "tungsten halogen" lamps. The bulbs soon caught on for spotlights and projectors and eventually for general lighting. Right now, because they are somewhat more efficient than the standard incandescent lamp, they are not on the chopping block in any country.

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